# IMPROVEMENT OF AIRBORNE BACTERIA LEVEL IN EXISTING AIR-CONDITIONING INSTALLATIONS

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## ABSTRACT

The Government of the Hong Kong Special Administrative Region (HKSAR) has set up an "Indoor Air Quality Management Group" (IAQMG) to establish an indoor air quality (IAQ) management programme which aims to protect public health in indoor environment and promote public awareness of the importance of IAQ. The programme is developed for offices and other public and commercial buildings with mechanical ventilation and air conditioning (MVAC) system. The IAQMG have published a draft Guidance Notes (GN) in 1999 and a draft Participation Guide and a draft Certification Guide in 2000 with a 2-level indoor air quality objectives in terms of 12 IAQ parameters. The Electrical & Mechanical Services Department (EMSD) of the HKSAR Government have taken the lead to survey all government venues with MVAC system, commencing 2000. The EMSD have also carried out studies on improvement initiatives for those parameters with concerns identified.

The Paper concentrates on what the EMSD have achieved on the airborne bacteria count objective, from measurement and laboratory work, to identification, investigation, improvement and subsequent analysis of concerns in existing MVAC systems.

**KEY WORDS:** Indoor air quality, management programme, airborne bacteria count, certification scheme, mechanical ventilation, air-conditioning system

## INTRODUCTION

On average, we spend more than 70% of our time at homes, in offices and other indoor environment. Good indoor air quality safeguards our health and contributes to our comfort. It can also improve productivity at the workplace. On the other hand, poor indoor air quality 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. Indoor air quality is also considered to be part of the broader concept of "healthy living".

The EMSD have taken the lead to survey all government buildings served by MVAC system, starting from 2000. During the survey, airborne bacteria level was found to be a parameter that attracted considerable concern. Detail studies on the identification, investigation, implementation and review of improvement initiatives was subsequently carried out.

## IAQ MANAGEMENT PROGRAMME OBJECTIVES

A 2-level IAQ objectives comprising 12 parameters was 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 indoor air quality. Level 1 represents very good indoor air quality that a high-class and comfortable 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. A summary of the Level 1 and 2 objectives is indicated in Appendix 1. For existing government buildings, it is aimed to achieve not less than level 2 standard.

## AIRBORNE BACTERIA AS A CONTAMINANT

In air-conditioned buildings, bacteria come from various channels, besides those from occupants and infiltration, water or condensation in ventilation system can act as breeding grounds for them, all of these are then dispersed through the ventilation process. In indoor environment, bacteria counts are naturally higher in crowded places and it is not meant to be a direct indicator of health risk but serve as screening tests for further investigation. There are various factors that result in high bacterial counts. High counts serve as an indicator for a combination of possible factors, which could include inadequate housekeeping, improper operation & maintenance of HVAC system, and necessary HVAC enhancement work to suit the changing site conditions and occupant activities. Further investigation should be carried out to identify the root causes so as to facilitate formulation and implementation of appropriate improvement measures.

## MEASUREMENT OF AIRBORNE BACTERIA LEVEL

Airborne bacteria have been quantified traditionally in "colony-forming units" (CFUs) per cubic metre (cfu/$m^3$) of air. As bacteria cannot be measured on real time basis, Anderson impacter samplers were used to sample the airborne bacteria with tryptic soy agar as cultural media. Sampling duration will be 5 minutes for every 2 hours during an eight-hour period. The collected samples are then incubated at 30°C for 48 hours. The CFUs on the agar surfaces are then counted to determine the viable bacteria in the environment.

## IMPROVEMENT OF AIRBORNE BACTERIA LEVEL – GENERAL APPROACH

For airborne bacteria level exceeds the limit as stipulated in the IAQ objectives, a series of investigations will be carried out to ascertain causes of high count and feasible improvements, followed by subsequent analysis.

**walk through survey & bacteria sampling**

The purpose of a walk through survey is to get a rough idea of the likely origins of the findings. In the survey, the airside of the HVAC system would be inspected to identify possible problem areas. Inspection includes areas such as water leakage/condensation dripping, outdoor intake positions and the environmental conditions of the vicinity. Daily operation & maintenance schedule of the HVAC system and the system settings will also be examined to find out possible problem areas and ways for improvements. Besides, outdoor air samples examination and indoor bacteria profile at different times of a day are necessary to reveal more information.

**HVAC system enhancement**

The Ventilation Rate Procedure in ASHRAE 62-1999 provides a simple & effective way to achieve IAQ objective. However, due to the ever-changing site conditions after completion of the HVAC installation, HVAC systems enhancement are very often necessary. Possible enhancement areas include increase of outdoor air supply rate for pollutant dilution, improve outdoor air supply pre-treatment to reduce bacteria intake through outdoor air supply, maintain positive building pressure to minimise bacteria intake via. infiltration, fix sewage leakage/condensation dripping to eliminate possible bacteria growth, remove air flow obstacles to maintain proper air flow at design conditions, clean the air filters and air ducts properly and regularly to eliminate bacteria incubation during non-operation hours, adjust system settings to suit the ever changing site conditions and occupant activities, and install air treatment and bacteria suppression devices such as special filters and UV sterilizers.

**housekeeping improvement**

Achieving indoor air quality is a multi-discipline teamwork, good housekeeping is an essential factor. Good housekeeping could include adequate cleaning procedure/schedule, timely replacement of contaminated carpets and ceiling tiles and prompt removal of water trapped under plants so that factors leading to high bacteria growth are illuminated/minimised. Besides, pest control should be carried out at regular intervals and at the right time with subsequent purging to reduce trapping of pesticide within the HVAC ducting system. Close co-ordination between building management and HVAC personnel is essential. No smoking policy should also be strictly enforced.

## IMPROVEMENT OF AIRBORNE BACTERIA LEVEL – A CASE STUDY

A case study was conducted in 9 office premises within venues of various natures. Four mitigation methods were included in the study. Airborne bacteria samples were collected before and after the implementation of the mitigation methods.

**re-arrangement of HVAC operation schedule**

Measurement results on airborne bacteria level showed that a longer purging time was effective to bring down the airborne bacteria count to a lower level during the occupancy period. The operating schedule of the HVAC system was arranged to start operating 2 hours earlier. The purpose of this measure was to provide sufficient time for purging of the airborne bacteria which incubated and grew inside the air ductworks and filters during the non-operation hours during nighttime or public holidays when the fresh air supply from the system was turned off. It was found that the airborne bacteria level was reduced by around 10% compared with the average airborne bacteria level in the morning.

**installation of molecular-sieve air treatment device**

A molecular-sieve air treatment device, which consisted of coarse dust filters, fine dust filters and molecular sieve columns, was used for the test. The filters were used to filter out the solid phase pollutants, which might probably consist of bacteria, organic substances, inorganic substances, carbon and its complex. The molecular sieves contained alkali aluminum silicates, which absorb nitrogen ($N_2$), carbon dioxide ($CO_2$), carbon monoxide (CO), formaldehyde (HCHO) and RSP while allowing the oxygen ($O_2$) to be extracted and discharged rapidly. The sieves were then flushed clean with part of the oxygen produced. The purpose of this method is to purify indoor air without changing the existing ventilation layout.

The device was allowed to run for 72 hours and the average indoor airborne bacteria level was reduced by around 60%. The indoor bacteria level was reduced significantly by running these air treatment devices because the pre-filter captured part of the particulate matters and the molecular sieve columns further removed the fine particles that might contained smaller biological organisms. Besides, the relative humidity was reduced from 78% to 67%. The reduction in RH also helped in reducing the indoor bacteria level as the water content in air facilitated the growth of bacteria.

**installation of ultraviolet sterilizer**

Ultraviolet lamps generating C-band (UVC) radiation with wavelength at around 254nm with no ozone production were used. The UV sterilizing system was installed at a position between the filters and the cooling coils. The direction of airflow was perpendicular to the UV lamp arrangement. The purpose of this mitigation method is to provide UVC to destroy the DNA's helix structure of the bacteria. The exposed cell (airborne bacteria) can no longer repair the resulting damage and the consequence is that the cell loses the ability to divide and reproduce. Eventually, the airborne bacteria dies and thus, the indoor bacteria level can be reduced.

After 50 hours of the installation and operation of the UV based treatment system, the indoor airborne bacteria level was reduced by around 20%.

**installation of zeolite filter**

Zeolite and granular activated carbon were porous materials with a large surface area to volume ratio enhanced the absorption ability of the air contaminants. The purpose of this mitigation method is to purify indoor air by both absorption and adsorption. The original filters for filtering particulate matters were replaced by zeolite based filter in the AHUs. The frames of the filters were reinforced in order to bear the weight of the filtering materials. The filtering materials consisted of zeolite (70% in wt.) and granular activated carbon (30% in wt.). Sheets of fibre filter were installed in the outer faces of each filter in order to prevent the fine ash from blowing out from the filtering materials.

With the zeolite filter installed and the AHU operated for 107 hours, the average indoor airborne bacteria level removal efficiency was around 25%.

**cost comparison of the methods**

a cost analysis of the four methods was evaluated based on one-year operation. The total cost for using the mitigation method in one year operation included initial cost, operation cost and maintenance cost. The initial cost consisted of the cost of installation and the cost of purchasing the device for each mitigation method divided by the life expectancy (in years) of the equipment. The operation cost was the additional electricity charge. The maintenance cost included the cost of replacing parts and cost of manpower for maintenance work. As each mitigation method served different size of sites, a per unit area approach is used.

Taking the UV sterilizing systems one-year operation cost per unit served area as the base. It was found out that the changing of HVAC operation pattern has a unit cost of around 8 times that of the UV system. The unit cost for molecular sieve air treatment and zeolite based filters are around 90 times and 4 times that of the UV system respectively.

## SUMMARY AND CONCLUSION

With the introduction of the indoor air quality management programme, people in the HKSAR are more and more concern with this issue. After some experimental work, EMSD revealed that airborne bacteria count is a concern that needs to have further study and follow up work. Besides conventional improvement initiatives, a case study was conducted with valuable findings. However, further studies on the same methods apply to other venues of different natures, and on other feasible methods are yet to take place. It is hoped that the work EMSD have achieved so far could attract more discussion, study and implementation trial for all parities to share and benefit so as to accomplish the ultimate IAQ objectives for the whole community

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## Appendix 1

### Recommended Indoor Air Quality Objectives for Office Buildings and Public Places in the HKSAR

| Parameter | Unit | 8-hr average | |
|---|---|---|---|
| | | Level 1 | Level 2 |
| Carbon Dioxide ($CO_2$) | ppm | < 800 | < 1,000 |
| Carbon Monoxide (CO) | μg/m$^3$ | < 2,000 | < 10,000 |
| Respirable Suspended Particulates (RSP) | μg/m$^3$ | < 20 | < 180 |
| Nitrogen Dioxide ($NO_2$) | μg/m$^3$ | < 40 | < 150 |
| Ozone ($O_3$) | μg/m$^3$ | < 50 | < 120 |
| Formaldehyde (HCHO) | μg/m$^3$ | < 30 | < 100 |
| Total Volatile Organic Compounds (TVOC) | μg/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 |

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